J. Field Ornithol., 64(4):566–574

DISTRIBUTION AND TRENDS IN ABUNDANCE OF ROUGH-LEGGED HAWKS WINTERING IN CALIFORNIA

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Abstract.—Distribution and trends in abundance of Rough-legged Hawks (*Buteo lagopus*) wintering in California were assessed using Christmas Bird Counts (CBCs). Data from 114 individual CBCs conducted in California over 40 yr during the winters of 1949–1950 to 1988–1989 were used. The percentage of CBCs with Rough-legged Hawks, average number of hawks/CBC, and average number of hawks/160 party-km/CBC were positively correlated with year ($P < 0.0001$) over the 40-yr period. The frequency distribution of intervals between statewide population peaks differed significantly ($P < 0.001$) from a random pattern, and was not significantly different ($P > 0.75$) from a 4-yr cycle. These results indicated that the peaks in wintering populations of Rough-legged Hawks are more cyclic than irregular. Rough-legged Hawk numbers were significantly ($P < 0.001$) different among eight geographic regions in California, and the greatest numbers of hawks were found in the North Interior and North and South Sierra Nevada regions. Significant positive correlations ($P < 0.05$) were found for average number of hawks/CBC and average number of hawks/160 party-km/CBC with year in all geographic regions except the North Sierra (both variables) and Central Coast (average number/CBC).

DISTRIBUCIÓN Y TENDENCIAS EN LA ABUNDANCIA DE INDIVIDUOS DE *BUTEO LAGOPUS* QUE PASAN EL INVIERNO EN CALIFORNIA

Sinopsis.—Utilizando censos de invierno (CBC) por un período de 40 años (1949–1950 hasta el 1988–1989) se determinó la distribución y tendencias de abundancia de 114 individuos del halcón *Buteo lagopus* que pasaron el invierno en California. El porcentaje de censos (CBC) con los halcones, número promedio de aves/CBC, el número promedio de halcones/160 grupos-km/CBC se correlacionaron positivamente con el año ($P < 0.0001$) a través de los 40 años incluidos en el estudio. La frecuencia de distribución de intervalos entre los picos poblacionales de todos los estados resultó significativamente diferente ($P < 0.001$) de un patrón al azar, y no así ($P > 0.75$) a un ciclo de cuatro años. Los resultados indican que los picos de las poblaciones invernales de estos halcones son más cíclicos que irregulares. El número de estas aves entre ocho regiones distintas de California resultó significativamente diferente ($P < 0.001$). El número mayor de halcones fue encontrado en la parte norte-interior, parte norte y sur de las regiones de la Sierra Nevada. Se encontraron correlaciones positivas significativas con el año ($P < 0.05$) para el número promedio de halcones/CBC, el número promedio de halcones/160 grupos-km/CBC en todas las regiones geográficas excepto la parte norte de la Sierra (para ambas variables) y la costa central (número promedio/CBC).

In North America, Rough-legged Hawks (*Buteo lagopus*) winter in grasslands and open country from southern Alaska and Canada to the southern parts of California, Arizona, New Mexico, Texas, Missouri, Tennessee and Virginia (American Ornithologists' Union 1983, Root 1988). The species breeds in open coniferous woods, tundra and barren country from western and northern Alaska across northern Canada (Zarn 1975).

Fluctuations in number and productivity of breeding Rough-legged

Hawks have been documented for several populations (Johnsgard 1990, Mindell et al. 1987, Mindell and White 1988, White and Cade 1971, Zarn 1975). These authors mostly attributed these fluctuations to changes in their primary prey populations, most lemmings (*Lemmus* spp.) and ground squirrels (*Spermophilus* spp.), which are known to display population cycles at approximately 4-yr intervals (Krebs and Myers 1974). Mindell and White (1988), however, found a stronger association between hawk numbers and climate, because hawks were able to shift prey species when populations of one prey species had declined.

Irregular fluctuations in numbers of wintering Rough-legged Hawks have been noted from central Colorado (Stahlecker 1975) and the northeastern United States (Titus et al. 1989). With these exceptions, there is little documentation of the population dynamics of wintering Rough-legged Hawks, and Harlow and Bloom (1989) concluded that long-term monitoring of winter populations should be conducted to assess population trends in the western United States.

Having begun in 1900, Christmas Bird Counts (CBCs) are the oldest and largest long-term population surveys of wintering bird species in North America (Butcher 1990). Data from CBCs have been used to study trends in winter population abundance and distribution of many North American bird species (e.g., Bock and Root 1981, Butcher 1990, Root 1988). CBCs are generally acknowledged as yielding useful data on the dynamics of wintering populations, but there are also acknowledged biases in the surveys (Bock and Root 1981, Butcher 1990, Butcher et al. 1990, Smith 1979).

Using 40 yr of data from CBCs in California, my study was conducted to determine trends in the abundance of wintering Rough-legged Hawks in California and to determine the geographical distribution of the wintering birds.

METHODS

CBCs conducted in mainland California during the winters of 1949–1950 to 1988–1989 and published in *American Birds* (formerly *Audubon Field Notes*) were searched for records of Rough-legged Hawks. As CBCs are conducted between mid-December and early January each winter, CBCs will be designated by the later year (e.g., 1950 for winter of 1949–1950) in this paper.

Data recorded from each CBC included number of hawks, total number of kilometers covered by observation parties (party-km), and total number of bird species. For each year, I calculated the average number of hawks/CBC, percentage of CBCs with hawks, average number of hawks/160 party-km/CBC, largest number of hawks counted in a single CBC, and average number of bird species recorded/CBC. Numbers were normalized as hawks/160 party-km/CBC to compensate for differences in search effort among CBCs (Bock and Root 1981, Butcher 1990, Raynor 1975).

For individual CBCs, I calculated the percentage of annual counts on which hawks were recorded, average number of hawks/yr and average

number of hawks/160 party-km/CBC. Average number of hawks/160 party-km/CBC was calculated by averaging the number of hawks/160 party-km across all count years. Individual CBCs were categorized into one of eight geographic regions in California used for the California Vegetation program (CALVEG) (Parker and Matyas 1979) (Fig. 1).

The frequency distribution for intervals between Rough-legged Hawk population peaks was compared to random fluctuation peaks and the 4-yr cycle for small mammal populations as calculated by Cole (1951). Cole's (1951) data have been used to study population cycles in the Northern Shrike (*Lanius excubitor*), which is another predatory bird of northern latitudes (Davis and Morrison 1987). A peak was defined as a number for a given year that is larger than the previous and succeeding years (Davis and Morrison 1987).

A total of 114 individual CBCs were used, but data were initially gathered from 144 CBCs. Thirty CBCs were eliminated because they were conducted <3 consecutive years, or conducted a total of 3 yr.

Data did not meet the assumptions necessary to use parametric statistics, even with appropriate transformations (Zar 1974), therefore non-parametric statistics were used. Spearman rank correlations (r_s) were used to assess long-term relationships between CBC population parameters and year for the state and eight geographic regions, and Kruskal-Wallis tests were used to assess whether population parameters differed among geographic regions. Mann-Whitney U tests were used to determine differences between populations from CBCs started on or before 1970 and those started after 1970. Frequency distributions of intervals between peaks were compared to the random and 4-yr cycle distributions calculated by Cole (1951) using χ^2-test of goodness-of-fit. Statistical significance was set at $P < 0.05$.

RESULTS

Over the 40-yr period, there were significant ($P < 0.001$) positive correlations between year and average number of hawks/CBC ($r_s = 0.869$, df = 38), percentage of CBCs with hawks ($r_s = 0.895$, df = 38), and average number of hawks/160 party-km/CBC ($r_s = 0.743$, df = 38) (Fig. 2). Numbers of Rough-legged Hawks became considerably greater beginning in 1970. The largest number of hawks/160 party-km in a single CBC was positively correlated with year ($r_s = 0.723$, df = 38, $P < 0.001$), and the percentage of CBCs with Rough-legged Hawks was positively correlated with average number of bird species recorded ($r_s = 0.879$, df = 38, $P < 0.0001$).

The percentage of CBCs with Rough-legged Hawks ($H = 25.68$, df = 7), average number of hawks/CBC ($H = 24.72$, df = 7), and average number of hawks/160 party-km/CBC ($H = 24.75$, df = 7) were significantly different ($P < 0.001$) among eight geographic regions in California (Table 1). The North Interior, North and South Sierra Nevada, and North Coast regions had the largest numbers of Rough-legged Hawks (Table 1). CBCs with the largest numbers of hawks in the North and

FIGURE 1. Geographic regions in California used to assess the distribution of wintering Rough-legged Hawks using Christmas Bird Counts from 1950 to 1989. Numbers for each region are regional averages for number of Rough-legged Hawks/160 party-km/CBC.

South Sierra Nevada were on the eastern slope of the Sierra Nevada mountains.

To assess localized population trends, Spearman rank correlations were individually conducted for the eight geographic regions and 17 individual CBCs. The 17 CBCs had been run for ≥ 20 yr with gaps between successive counts of ≤ 1 yr, and Routh-legged Hawks were recorded on >25% of the annual counts. Significant ($P < 0.05$) positive correlations with year ($r_s = 0.391$–0.785, df = 21–38) were found for average number of hawks/CBC and average number of hawks/160 party-km/CBC for all

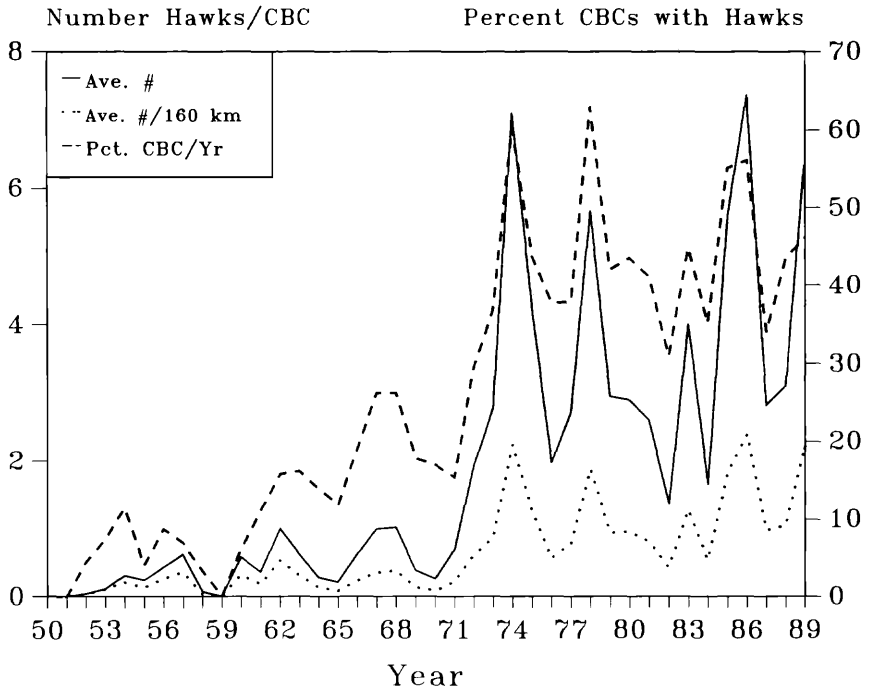

FIGURE 2. Average number/CBC, average number/160 party-km/CBC, and percentage of CBCs with Rough-legged Hawks from Christmas Bird Counts (CBCs) in California, 1950–1989.

geographic regions except the North Sierra for both variables and Central Coast for average number of hawks/CBC. Twelve of 17 (70.6%) CBCs had significant ($P < 0.05$) positive correlations with year (r_s = 0.392–0.760, df = 18–38) for average number of hawks/CBC, and 11 of

TABLE 1. Averages for percentage of Christmas Bird Counts (CBCs) with Rough-legged Hawks, number of hawks/CBC, and number of hawks/160 party-km/CBC for eight geographic regions in California from CBCs from 1950 to 1989.

Region	# CBCs	%	#/CBC	#/160 km/CBC
North coast	18	43.5	3.33	0.91
North interior	6	78.0	33.77	16.32
North Sierra	4	53.1	5.47	2.93
Central valley	21	54.6	3.14	1.00
Central coast	21	32.3	0.91	0.40
South Sierra	7	53.9	4.00	2.98
South interior	13	21.6	0.44	0.19
South coast	24	17.4	0.27	0.12
P-value[a]		0.0006	0.0009	0.0008

[a] Kruskal-Wallis test.

TABLE 2. Frequency distribution of intervals between peaks (%) in numbers of Rough-legged Hawks in California from Christmas Bird Counts (CBCs) from 1950 to 1989. Percentages are in parentheses.

Intervals (yr)	% random cycle[a]	% 4-year cycle[a]	Mean #/CBC and mean #/160 party-km/CBC	% CBCs with hawks
2	39.1	25.0	1 (11.1)	1 (12.5)
3	34.4	25.0	3 (33.3)	1 (12.5)
4	17.4	18.8	1 (11.1)	2 (25.0)
5	6.5	12.5	2 (22.2)	2 (25.0)
6	1.9	7.8	2 (22.2)	1 (12.5)
≥7	0.7	10.9	0 (0.0)	1 (12.5)
Total	100.0	100.0	9 (99.9)	8 (100.0)
Mean interval (yr)	3.00	4.00	4.11	4.50

[a] Percentages calculated by Cole (1951).

17 (64.7%) CBCs had significant ($P < 0.05$) positive correlations with year ($r_s = 0.380–0.786$, df = 18–38) for average number of hawks/160 party-km/CBC. Rough-legged Hawk numbers generally began increasing around 1970 for those regions and individual CBCs with relatively large numbers of birds. Population increases were less obvious for regions and CBCs with relatively low numbers of Rough-legged Hawks (e.g., South Coast and South Interior).

For the entire state, the frequency distribution of intervals between peaks for average number of hawks/CBC ($\chi^2 = 21.6$, df = 4), average number of hawks/160 party-km/CBC ($\chi^2 = 21.6$, df = 4), and percentage of CBCs with hawks ($\chi^2 = 23.5$, df = 4) were significantly different ($P < 0.001$) from Cole's random distribution (Table 2). The frequency distribution of peaks for the same three variables for the statewide values were not different ($P > 0.75$) from Cole's 4-yr cycle distribution. In addition, for six of the eight geographic regions, frequency distributions of peaks were not different ($P > 0.75$) from Cole's distribution for the 4-yr cycle and random distribution for 23 of 24 (95.8%) possible tests (North Sierra and North Interior were not tested because the frequency table was too sparse). The frequency distribution of intervals between peaks was significantly different ($P < 0.005$) from a random distribution for average number of hawks/CBC for the Central Valley.

DISCUSSION

Three population parameters of Rough-legged Hawks wintering in California were positively correlated with year over the 40-yr study period. The positive correlations could be interpreted as indicative of an increasing wintering population. The apparent increase is supported by significant positive correlations for seven of eight geographic regions and >64% of 17 individual CBCs. It is also possible, however, that the significant positive relationship between the average number of bird species/CBC and percentage of CBCs with Rough-legged Hawks indicates that hawk

observations may have increased along with increased effort or improvements in identification skills, optical equipment and field guides. Smith (1979) found that improvements in skills and equipment were the most likely explanation for increases in number of bird species observed in CBCs.

Increased awareness of raptors since the 1970s may have played a role in the apparent increase, because Rough-legged Hawks and other rare raptors may be target species and receive greater search effort during CBCs (Butcher and McCulloch 1990). Duplicate counting and misidentification may also have been factors, although CBC participants try to minimize these problems (Butcher 1990).

These increases could not be fully explained by the addition of new CBCs after 1970 in areas with relatively large populations of wintering Rough-legged Hawks, as was the case with Ferruginous Hawks (*B. regalis*) wintering in California (Garrison 1990). The percentage of CBCs with hawks from older CBCs, however, was approximately 50% less than younger CBCs and approached statistical significance ($P < 0.09$). Younger CBCs were generally located in remote, less developed areas where hawk populations are greater.

Statewide, long-term increases were punctuated by population peaks with average intervals of 4.11–4.50 yr. Within California's eight geographic regions, population peaks were fairly obvious to discern from a visual interpretation of the data, but there were no statistically significant differences from 4-yr and random cycles.

Fluctuations in numbers of wintering Rough-legged Hawks with peaks occurring from 3 to 5 yr have been reported from other long-term analyses of CBCs in central Colorado (Stahlecker 1975) and the northeastern United States (Titus et al. 1989). Also, wintering population fluctuations averaging 3–4 yr for other raptors breeding in northern latitudes have been reported using CBC data for the Snowy Owl (*Zyctea scandiaca*) (Kerlinger et al. 1985, Smith and Ellis 1989) and Northern Shrike (Davis and Morrison 1987).

Fluctuations in size of breeding populations may cause fluctuations in wintering populations. This explanation is difficult to verify with CBC data due to lack of knowledge about sources of the wintering populations and dynamics of breeding hawk populations and their prey populations. Also, wintering Rough-legged Hawk populations fluctuate due to environmental factors on the wintering grounds such as abundance of prey and amount of snow and vegetative cover (Baker and Brooks 1981, Watson 1986). These relationships are variable, however, because Craig et al. (1984) did not find a relationship between Rough-legged Hawk numbers and abundance of black-tailed hare (*Lepus californicus*) carrion. Davis and Morrison (1987) could not reliably determine the causes of cyclicity in the Northern Shrike using CBC data.

According to CBC data, wintering populations of Rough-legged Hawks in California are generally smaller on average than wintering populations throughout North America where populations are greatest in the Great

Basin and Great Plains (Johnsgard 1990, Root 1988). Rough-legged Hawk populations in some parts of California, however, are relatively large compared to other North American CBCs. For example, between 1970 and 1989, a California CBC recorded the greatest number of Rough-legged Hawks in North America in five of the 20 (25%) count years. These CBCs were located in California's North Interior region, which is part of the Great Basin province, where Rough-legged Hawk wintering populations are relatively large.

Regions in California that supported the greatest numbers of Rough-legged Hawks were the North Interior, North and South Sierra Nevada, and Central Valley which are dominated by open habitats such as grasslands, agricultural areas and desert scrub. These habitats are commonly utilized by wintering Rough-legged Hawks (Johnsgard 1990). Individual CBCs with the largest numbers of hawks were in the North Interior at or near Tule Lake National Wildlife Refuge and Honey Lake State Wildlife Area. Increased numbers of wintering birds around wildlife refuges have been previously documented with CBC data (Root 1988). The smallest numbers of hawks wintering in California were found in the more southern and central coastal and interior regions where climates are milder than in the colder northern regions.

The vegetative structure of the primary wintering areas in California are similar to the tundra and non-forested habitats of Rough-legged Hawk breeding grounds in Alaska and northern Canada. A similar relationship has been noted with Ferruginous Hawks because they tend to migrate and winter in habitats similar to their breeding grounds (Garrison 1990, Schmutz and Fyfe 1987).

ACKNOWLEDGMENTS

I thank Mike Morrison, Linnea Hall and two anonymous reviewers for commenting on earlier drafts of this paper. Page charges were paid by the Nongame and Threatened Bird and Mammal Section, California Department of Fish and Game.

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Received 23 Dec. 1992; accepted 12 May 1993.